Incorporation of Recycled Plastic in Pavement Construction

Deepak Aggarwal[1], Rahul Kumar[2]

[1]*Assistant Professor, Department of Civil Engineering, SCET Ghaziabad, UP, India*
[2]*Assistant Professor, Department of Civil Engineering, SCET Ghaziabad, UP, India*

***

Abstract - *Plastic waste is a significant resource, commonly found in solid waste and often discarded without proper treatment. Municipal plastic waste disposal, particularly in urban areas, has grown tremendously, impacting the aesthetic of landscapes. Plastic has proven to be a useful binder in bitumen mixes used for flexible pavements. This innovative approach enables pavements to withstand higher temperatures by reducing crack formation and rainwater infiltration, which typically leads to pothole development. These roads demonstrate enhanced resistance to crushing and abrasion and experience less water seepage. In India's hot and highly humid climate, where temperatures often exceed 50°C and heavy rains wreak havoc on infrastructure, plastic roads could be a game-changer by reducing the occurrence of large potholes.*

Bituminous Concrete (BC), a composite material widely used in road surfaces, airports, and parking areas, is composed of asphalt or bitumen (acting as a binder) and mineral aggregates. These components are mixed, layered, and compacted to form durable surfaces. Today, the steady rise in high traffic volumes, especially commercial vehicles, combined with daily and seasonal temperature variations, prompts a need for alternatives that can improve pavement durability and quality while remaining cost-effective.

From an environmental standpoint, the excessive use of polythene in everyday activities has led to significant pollution. Since polythene is non-biodegradable, there is a pressing need to find beneficial applications for this waste, and using it in road construction presents a promising solution.

***Key Words*: Recycled Plastics, Bituminous Binders, Construction Aggregates, Sustainable Plastic Roads, Plastic Bituminous Aggregate mix.**

1.INTRODUCTION

Most paved roads in our country are constructed with a granular sub-base and base, as well as bituminous base and surface layers. Plastic, known for its versatility, became widely used due to the industrial revolution and mass production, making it a cheap and effective raw material. Plastics now play a crucial role across nearly every economic sector—from agriculture to packaging, automotive, electronics, construction, and communication. However, plastic is non-biodegradable, with research showing that it can persist in the environment for up to 4,500 years without breaking down. Numerous studies have highlighted the environmental and health risks posed by improper plastic waste disposal. While plastic is beneficial to society, it poses significant environmental challenges after use. The eco-friendly disposal of various plastic and rubber wastes has become a key focus in current research efforts. Given today's lifestyle, completely banning plastic use is challenging, even though it has become a major pollution problem for present and future generations.

Nevertheless, using waste plastics in road construction is gaining popularity, as plastic roads have shown better performance compared to traditional roads, repurposing what would otherwise contribute to pollution. Applying waste plastic to coat the aggregates in bituminous mixes has been found to enhance performance. Recycled polyethylene bags, shredded into small pieces, are coated onto the aggregate at a specific temperature. Bituminous mixes are then prepared using 60/70-grade bitumen, either with plastic-coated or conventional aggregates, and cement as a filler material. The inclusion of plastic waste significantly improves the abrasion resistance and slip resistance of flexible pavements, and enhances the mix's tensile strength values.

2.LITRATURE SURVEY

1. In 1942, Fransis Hveem, a project engineer with the California Department of Highways, sought to determine the optimal amount of bitumen for road construction. Without prior experience in assessing mix quality by appearance, he devised the Hveem stabilometer in 1927 to measure specific mixture parameters, enabling accurate bitumen quantity estimations based on surface area calculations—a method adapted from cement concrete mix design at the time (Vallerga and Lovering, 1985).

2. Sabina (2001) examined the properties of bituminous mixes containing plastic or polymer (PP) at 8% and 15% by bitumen weight, comparing them with conventional bituminous concrete made with 60/70 penetration-grade bitumen. Her research showed that plastic-modified bituminous concrete mixes had increased Marshall Stability, retained stability, indirect tensile strength, and reduced rutting.

3. Justo and his team (2002) at Bangalore University's Centre for Transportation Engineering experimented with processed plastic bags as additives in asphalt mixes. They observed that with higher proportions of plastic additives, the penetration and ductility values of bitumen declined, enhancing the mix's performance under specific conditions.

4. In 2007, Dr. R. Vasudevan discovered that coating aggregates with plastic reduces porosity, decreases moisture absorption, and enhances durability. He concluded that a polymer-bitumen blend serves as a superior binder compared to plain bitumen, with improved softening points, reduced penetration values, and suitable ductility. When applied in road construction, this blend tolerates higher temperatures and heavier loads. The plastic-coated aggregate-bitumen mix exhibits higher Marshall Stability and a suitable Marshall Coefficient, making it ideal for flexible pavement construction. This method offers an effective solution for waste plastic disposal, enhancing road quality while addressing pollution issues.

5. Finally, S. Rajasekaran et al. (2009) conducted Marshall's mix design experiments with modified bitumen and constant optimum rubber content. The study revealed significant improvements in various characteristics of the bitumen mix compared to conventional (60/70) bitumen, demonstrating enhanced durability and performance attributes.

6. In 2013, Amit P. Gawande assessed the economic feasibility of plastic-modified roads. His analysis of asphalt concrete with 3% crumb rubber showed a substantial improvement in flexural fatigue life and creep properties compared to unmodified asphalt mixes.

7. In 2013, S. Rajasekaran highlighted that coating aggregates with polymers not only enhances pavement quality but also improves aggregate durability. This technique helps dispose of plastic waste from household and industrial packaging, and the dry process effectively repurposes up to 80% of waste polymers in an eco-friendly manner. Additionally, using polymers reduces the amount of bitumen needed, thereby lowering road construction costs.

8. Vatsal Patel and colleagues (2014) examined the impact of additives such as EVA (Ethyl Vinyl Acetate), aromatic resin, and SBS on waxy bitumen. They found that adding 4% EVA, 6% SBS, or 8% resin effectively decreased susceptibility to high temperatures, minimized bleeding, and reduced brittleness in low-temperature conditions.

9. In 2015, Anzar Hamid Mir studied the viscoelastic properties of binders for road pavement construction. He discovered that the complex modulus and phase angles of binders should be evaluated under conditions that mimic real-world temperatures and loading rates to improve the accuracy of performance predictions.

10. Sasane Neha B. et al. (2015) explored the use of polyethylene, specifically HDPE and LDPE, to improve asphalt mix properties. The study found that HDPE as a 12% modifier by bitumen weight improved stability, slightly increased air voids, and reduced density, yielding better engineering properties for the mix.

11. Kurmadasu Chandramouli et al. (2016) reported that polyethylene-modified binders in asphalt concrete exhibited improved resistance to permanent deformation at high temperatures and better stripping resistance in crumb rubber-modified mixes than in standard asphalt mixtures.

12. Wayal and Wagle investigated the use of waste plastic and rubber in bituminous mixes for road construction. Their study used polymer and crumb rubber as binders with aggregates and bitumen. Tests were conducted for parameters such as crushing value, impact value, abrasion resistance, specific gravity, penetration, ductility, and softening point. They concluded that using waste plastic and rubber as a powdered additive for flexible pavements is an excellent method for managing waste disposal while improving road material properties.

3.OBJECTIVE

1. To create Marshall Stability samples incorporating plastic waste and without plastic waste.

2. To conduct the Marshall Stability test on prepared samples.

3. To compare the characteristics of conventional bituminous roads with those enhanced by recycled plastic additives.

4. To determine the ideal proportion of waste plastic for achieving optimal strength in the bitumen mix.

5. To mitigate the environmental issue of plastic waste disposal.

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 11 Issue: 11 | Nov 2024 www.irjet.net p-ISSN: 2395-0072

4.METHODOLOGY

The following steps have been incorporate detailed methodology.

Segregation - Plastic waste collected from various sources is carefully sorted to separate it from other materials. This thorough sorting process ensures the plastic waste is free of contaminants, facilitating efficient processing and smooth integration into bituminous mixtures.

Fig-1 Segregation of Plastic waste

Cleaning Process - The sorted plastic waste is subjected to thorough cleaning and drying to eliminate any contaminants, debris, or moisture. This essential step ensures the plastic waste meets quality standards for use in road construction. Clean, dry plastic waste improves particle adhesion and uniform distribution within the bituminous mix, contributing to enhanced pavement durability and performance.

Fig-2 Cleaning Process of Plastic Waste

Shredding Process:- The cleaned plastic waste is finely shredded or chopped into small, consistent pieces to ensure uniform distribution within the bituminous mix. This process allows plastic particles to be evenly dispersed throughout the mixture, enhancing the stability, durability, and performance of the resulting pavement.

Fig-3 Shredding of Plastic waste

Collection Process - Plastic waste particles retained on a 2.36 mm IS sieve are carefully gathered for further processing and integration into the bituminous mix. By selecting the ideal particle size, this step ensures optimal compatibility and bonding between the plastic particles and other components, thereby enhancing the overall performance of the pavement.

Fig-4 Collection of Plastic waste

5.RESULT AND DISCUSSION

Result and discussion: Material Testing - A range of tests are performed on both aggregates and bitumen to thoroughly assess their properties. These evaluations include:

Tests to be performed on aggregate:

Aggregate Impact Value Test: Measures the ability of aggregates to withstand sudden impacts or shocks.

Los Angeles Abrasion Test: Determines the resistance of aggregates to wear and abrasion.

Water Absorption Test: Evaluates the water absorption capacity of aggregates, which reflects their porosity and potential for moisture damage.

Specific Gravity Test: Measures the density of aggregates in comparison to water.

Stripping Value Test: Examines the bond strength between aggregate and bitumen, indicating the mix's resistance to moisture-induced separation.

Aggregate Crushing Test: It is used to assess the compressive strength of aggregates, which is crucial for understanding their ability to resist crushing under applied loads. Aggregates with a low crushing value are preferred for high-strength, durable pavements, as they are less likely to break down under heavy use.

Tests to be performed on bitumen:

Penetration Value Test: Assesses the hardness or consistency of bitumen.

Ductility Test: Measures the ability of bitumen to stretch, showing its flexibility and elongation properties.

Flash & Fire Point Test: Determines the temperatures at which bitumen becomes flammable and combustible.

Softening Point Test: Identifies the temperature at which bitumen begins to soften.

Sample Preparation:

Marshall Stability samples are created with varying amounts of plastic waste (such as 5%, 10%, and 15%) alongside control samples without plastic. This addition of plastic waste in the bituminous mix is precisely adjusted to examine its effects on pavement qualities like stability, durability, and resilience to temperature and moisture.

Marshall Stability Testing: Marshall Stability tests are performed on all samples to assess their behavior under simulated load conditions. This test evaluates the pavement's resistance to deformation and failure under compressive forces, providing key insights into the structural performance of plastic-modified pavements versus traditional bituminous mixes.

By following this detailed methodology, the study aims to systematically evaluate the advantages of adding plastic waste to bituminous mixes for road construction. Through thorough testing and analysis, it explores how plastic modification influences pavement properties and overall performance, offering valuable contributions to sustainable infrastructure practices and environmental conservation efforts.

Table-1: Results of tests on aggregate

Stone Aggregate	Plastic Content (%)	Aggregate Impact Value (%)	Los Angeles Abrasion Value (%)	Specific Gravity	Water Absorption (%)	Stripping Value (%)	Aggregate Crushing Value (%)
Sample without Plastic	0	13.5	14.85	2.60	0.5	3	22
Sample with Plastic	10	10.5	11.75	2.75	0.45	0	17.5
	12	9.27	10.60	2.81	0.40	0.5	15.5
	15	8.90	9.85	2.92	0.35	1	12.4

Table-2: Results of tests on Bitumen

Test	Result	Range
Ductility test	76.40 cm	Minimum 40 cm
Penetration value	81 mm	80-100 mm
Softening point	46.25° C	45-60° C
Flash point test	285° C	> 175° C
Fire point test	305° C	>175° C

Table-3: Marshall Stability and flow value

Sample No.	Bitumen content (%)	Plastic content (% by weight)	Marshall stability(kg)	Flow value (mm)
1	4	0	955	3.2
2	5	0	1175	3.3
3	6	0	1250	3.5
4	4	10	1715	4.2
5	5	12	1820	4.6
6	6	15	1920	5

Chart 1 : - Stability (kg) and Bitumen Content (%)

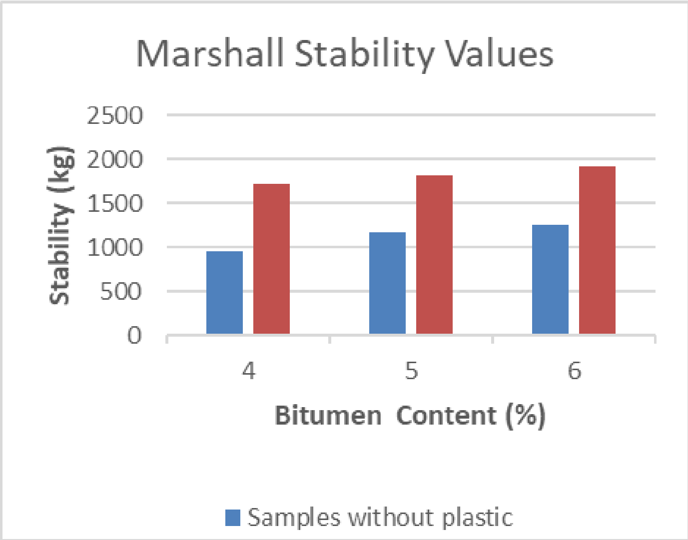
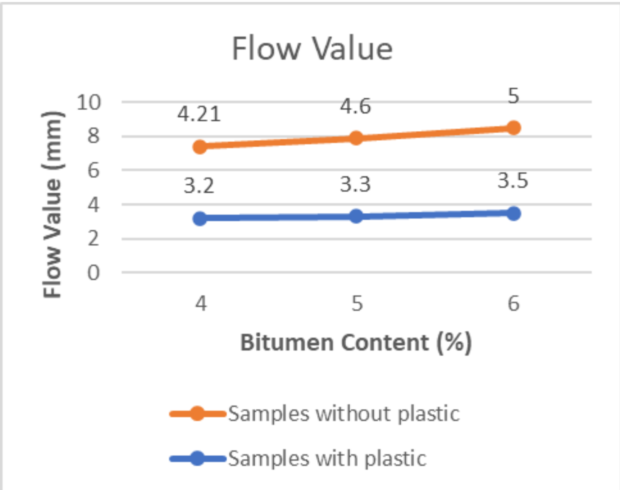


Chart 2 : - Flow Value (mm) and Bitumen Content (%)



6.CONCLUSION

This study demonstrates that incorporating waste plastic into bituminous mixes offers significant potential to improve pavement performance while addressing environmental challenges associated with plastic waste. By identifying the ideal amount of plastic to incorporate and promoting sustainable road construction practices, a pathway to stronger, more eco-friendly infrastructure becomes clear. Plastic-modified pavements show improved durability, temperature stability, and resistance to moisture, making them especially suited for areas with harsh climates, such as those in India.

This research makes a valuable contribution to both infrastructure advancement and environmental protection by advocating the reuse of plastic waste in road construction, reducing plastic pollution while enhancing pavement quality.

In essence, utilizing plastic waste in road development provides an effective solution to environmental issues and elevates infrastructure standards. With continued research, innovative approaches, and well-planned implementation, plastic-modified pavements offer a sustainable path toward a resilient transportation system, benefiting communities and ecosystems alike. This approach encourages a circular economy, repurposing waste materials to build durable assets, and supporting a greener, more sustainable future for generations ahead.

REFERENCES: -

1. Amit Gawande, G.S Zamre, V.C Renge G.R Bharsakalea and SaurabhTayde, utilization of waste plastic in asphalt of roads, scientific reviews and chemical communication.

2. Dr. Satish Chandra, Shiv Kumar & Rajesh Kumar Anand, “Soil Stabilization with Rice Husk Ash and line Sludge”, India Highways, Indian Roads Congress, vol33 No. 5, May 2005, pp.87-98

3. Dr. S.S.Verma, “Road from Plastic state.”,ScienceTech Entrepreneur, March 2008 Gianni A.K. Modi, A.J., “Bio Enzymatic Soil Stabilizers for Construction of Rural Roads”, International Seminar on Sustainable Development in Road Transport, New Delhi-India 8-10November 2001

4. IRC: SP: 20-2002. “Rural Roads Manual”, Indian Roads Congress

5. Mroueh, U. M., and Wahlstrom, M. (2002). “By-Products and Recycled Materials in Earth Construction in Finland M an Assessment of Applicability.” Resources, Conservation and Recycling, No. 35,2002, pp. 117M129

6. Miss Aproova ,use of plastic waste in flexible pavements, international journal of innovative research in engineering and management

7. Sherwood, P. T. (1995). “Alternative materials in road construction. “Thomas Telford Publications, London, 1995

8. Tara Sen, Umesh Mishra, “Usage of Industrial Waste Products in Village Road Construction,” International Journal of Environmental Science and Development, Vol. 1, No. 2, June 2010

9. Vasudevan .R, utilization of waste plastics for flexible pavement, Indian High Ways (Indian Road Congress), Vol.34, No.7. (July 2006).

10. Sabina (2001) examined the properties of bituminous mixes containing plastic or polymer (PP) at 8% and 15% by bitumen weight, comparing them with conventional bituminous concrete made with 60/70 penetration-grade bitumen

11. Wes Heidenreich, “Recycled plastic in highway construction and maintenance.” State Research report #525,July 1997.

BIOGRAPHIES

Mr. Deepak Aggarwal is presently working as an Assistant Professor in the Department of Civil Engineering at Sanskar College of Engineering and Technology, Ghaziabad, UP, India.

Mr. Rahul Kumar is presently working as an Assistant Professor & Head in the Department of Civil Engineering at Sanskar College of Engineering and Technology, Ghaziabad, UP, India. He has published so many research papers in national and international journals.